# *Townsendia rothrockii* Gray ex Rothrock (Rothrock's Townsend daisy): A Technical Conservation Assessment

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**Rocky Mountain Region,**
**Species Conservation Project**

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## COVER PHOTO CREDIT

*Townsendia rothrockii* (Rothrock's Townsend daisy). Photograph by William Jennings. Reprinted with permission from the photographer.

# SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *TOWNSENDIA ROTHROCKII*

## *Status*

*Townsendia rothrockii* (Rothrock's Townsend daisy) is a perennial forb endemic to central and southwestern Colorado occurring from 2,438 to 4,115 meters (m) (8,000 to 13,500 feet [ft]) on exposed limestone, sandstone, and volcanic substrates in alpine, subalpine, and montane environments (Beaman 1957, Colorado Natural Heritage Program 2003, Colorado State University Herbarium 2003, University of Colorado Herbarium 2003, NatureServe 2004, Rocky Mountain Herbarium 2004). *Townsendia rothrockii* is the focus of an assessment because it is a rare species with viability concerns due to its regional endemism, small number of documented occurrences, and possible human-related and environmental threats. Currently, 33 of the 35 known occurrences of this species occur on USDA Forest Service lands; the other two occurrences are on Colorado Bureau of Land Management land. This species is not listed on the USDA Forest Service Rocky Mountain Region sensitive species list (USDA Forest Service 2003) or the U.S. Fish and Wildlife Service threatened or endangered species list. The Global Heritage status rank for *T. rothrockii* is G2 (imperiled globally), and the Colorado Natural Heritage Program state heritage rank is S2 (imperiled in state) (D. Anderson personal communication 2004).

## *Primary Threats*

*Townsendia rothrockii* is vulnerable because of its endemic distribution, small number of documented occurrences, and possible human-related and environmental threats. Although 33 of 35 occurrences are on lands managed by the USDA Forest Service Rocky Mountain Region, this species is not specifically protected as a sensitive species. Inadequate abundance data or demographic information are available to conclude whether populations of *T. rothrockii* are increasing, decreasing, or remaining stable. Disturbances and land management activities may maintain suitable habitat for this species, or they may negatively impact existing populations, depending on the intensity, frequency, and type of the disturbances. Possible human-related threats to *T. rothrockii* include motorized and non-motorized recreation, road and structure construction, erosion and sedimentation related to roads, grazing activities, exotic species invasion, small-scale mining, and any changes to natural disturbance regimes. The extent of these activities near existing populations of *T. rothrockii* or in suitable *T. rothrockii* habitat is unknown. Environmental and biological threats to populations of *T. rothrockii* include succession, environmental fluctuations, herbivory, genetic isolation, inadequate pollination, global climate changes, and changes to the natural disturbance regime.

## *Primary Conservation Elements, Management Implications and Considerations*

The complete distribution and abundance of *Townsendia rothrockii* are not known. The microhabitat needs of this species and the intensity, frequency, and type of disturbances optimal for persistence of this species are unknown. The lack of information regarding the colonizing ability, adaptability to changing environmental conditions, sexual and asexual reproductive potential, and genetic variability of this species makes it difficult to predict its long-term vulnerability. Surveying high probability habitat for new populations, protecting existing populations from direct damage, documenting and monitoring the effects of current land-use activities, and preventing non-native plant invasions are key conservation elements for *T. rothrockii*. Priorities of future research studies include re-visiting and detailed mapping of the extent of existing populations, surveying to locate additional populations within USFS Region 2, assessing imminent threats, investigating factors affecting spatial distribution (e.g., microhabitat characteristics), studying taxonomic status, exploring biological and ecological limitations, and producing information related to reproductive mechanisms, demography and genetic structure.

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# INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project of the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS). *Townsendia rothrockii* (Rothrock's Townsend daisy) is the focus of an assessment because it is a rare species with viability concerns due to its regional endemism, small number of documented occurrences, and possible human-related and environmental threats. Such a rare species may require special management, so knowledge of its biology and ecology is critical.

This assessment addresses the biology of *Townsendia rothrockii* throughout its entire range, all of which is in USFS Region 2. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

## *Goal*

Species conservation assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, conservation status, and management of certain species based on available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations but provides the ecological background upon which management must be based. However, it does focus on the consequences of changes in the environment that result from management (i.e., management implications). Additionally, the assessment cites management recommendations proposed elsewhere, and, when management recommendations have been implemented, the assessment examines the success of the implementation.

## *Scope*

This assessment examines the biology, ecology, conservation status, and management of *Townsendia rothrockii* with specific reference to the geographic and ecological characteristics of USFS Region 2. Where supporting literature used to produce this species assessment originated from investigations outside the region (e.g., studies of related species), this document places that literature in the ecological and social context of the central Rockies. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *T. rothrockii* in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting the synthesis but placed in a current context.

In producing the assessment, we performed an extensive literature search to obtain material focusing on *Townsendia rothrockii*, as well as related information on the geographical and environmental context of this species. We reviewed refereed literature (e.g., published journal articles), non-refereed publications (e.g., unpublished status reports), dissertations, data accumulated by resources management agencies (e.g., Natural Heritage Program [NHP] element occurrence records), and regulatory guidelines (e.g., USDA Forest Service Manual). We did not visit every herbarium with specimens of this species, but we did incorporate all specimen label information in the Colorado NHP element occurrence records as well as specimen information available in Colorado State University Herbarium (2003), University of Colorado Herbarium (2003), and Rocky Mountain Herbarium (2004) databases. While this assessment emphasizes refereed literature because this is the accepted standard in science, non-refereed publications and reports are used extensively in because they provided information unavailable elsewhere. These unpublished, non-refereed reports were regarded with greater skepticism, and we treated all information with appropriate uncertainty.

## *Treatment of Uncertainty*

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, it is difficult to conduct experiments that produce clean results in the ecological sciences. Often, observations, inference, good thinking, and models must be relied on to guide our understanding of ecological relations. Confronting uncertainty then is not prescriptive. In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate.

Because of a lack of experimental research efforts concerning *Townsendia rothrockii*, this assessment relies heavily on the personal observations of botanists

and land management specialists from throughout the species' range. When information presented in this assessment is based on our personal communications with a specialist, we cite those sources as "personal communication" Unpublished data (e.g., NHP element occurrence records and herbarium records) were also important in estimating the geographic distribution and in describing the habitat of this species. These data required special attention because of the diversity of persons and methods used to collect the data, and unverified historical information.

Because there is a paucity of knowledge specific to this species, we also incorporated information, where available, from other *Townsendia* species or taxonomically related genera endemic to USFS Region 2 or adjacent states. These comparisons are not meant to imply that *T. rothrockii* is biologically identical to these species, but they represent an effort to hypothesize about *potential* characteristics of this species. Although the reproductive biology of *Townsendia* species has been the subject of preliminary investigative study (Beaman 1954, Beaman 1957), details concerning the reproductive biology of *T. rothrockii* are largely inferred or unknown. Ongoing studies on the genetic variability of other *Townsendia* species (e.g., *T. hookeri* [Thompson 2001]) may provide helpful insights on important issues to consider when studying the biology and conservation of *T. rothrockii*. As a result, biology, ecology, and conservation issues presented for *T. rothrockii* in USFS Region 2 are based on inference from these published and unpublished sources. We clearly noted when we were making inferences based on the available knowledge to inform our understanding of *T. rothrockii*.

### *Publication of Assessment on the World Wide Web*

To facilitate use of species assessments in the Species Conservation Project, they are being published on the USFS Region 2 World Wide Web site. Placing documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More importantly, it facilitates their revision, which will be accomplished based on guidelines established by USFS Region 2.

### *Peer Review*

Assessments developed for the Species Conservation Project have been peer reviewed prior to release on the Web. This assessment was reviewed through a process administered by the Society for Conservation Biology, employing at least two recognized experts on this or related taxa. Peer review was designed to improve the quality of communication and to increase the rigor of the assessment.

## MANAGEMENT STATUS AND NATURAL HISTORY

*Townsendia rothrockii* is a regional endemic species of Colorado and is known from approximately 35 occurrences globally (**Figure 1**, **Table 1**; Beaman 1957, Colorado Natural Heritage Program 2003, Colorado State University Herbarium 2003, University of Colorado Herbarium 2003, NatureServe 2004, Rocky Mountain Herbarium 2004). This section discusses the special management status, existing regulatory mechanisms, and biological characteristics of this species.

### *Management and Conservation Status*

#### Federal status

*Townsendia rothrockii* is not listed on the U.S. Fish and Wildlife Service (USFWS) threatened or endangered species list, the USFS Rocky Mountain Region sensitive species list (USDA Forest Service 2003), or the Colorado Bureau of Land Management (BLM) sensitive species list (U.S. Bureau of Land Management 2000).

#### Heritage program ranks

The Global Heritage status rank for *Townsendia rothrockii* is G2 (imperiled globally), and the Colorado NHP state heritage rank is S2 (imperiled in state). The NatureServe (2004) Web site indicates these ranks are associated with uncertainty (G2?/S2?), but David Anderson, botanist with the Colorado Natural Heritage Program, confirmed that there is no longer any uncertainty associated with the ranks; the NatureServe Web site has not been updated to reflect this yet. Heritage databases draw attention to species of special concern potentially requiring conservation strategies for future success. However, these lists are not associated with specific legal constraints, such as limiting plant harvesting or restricting damage to critical habitats.

*Townsendia rothrockii* is not known from Kansas, Nebraska, South Dakota, or Wyoming and is thus not currently listed or ranked in those states (Fertig and Heidel 2002, Kansas Natural Heritage Inventory 2002, Nebraska Natural Heritage Program 2002, South Dakota Natural Heritage Program 2002, Wyoming Natural Diversity Database 2003).

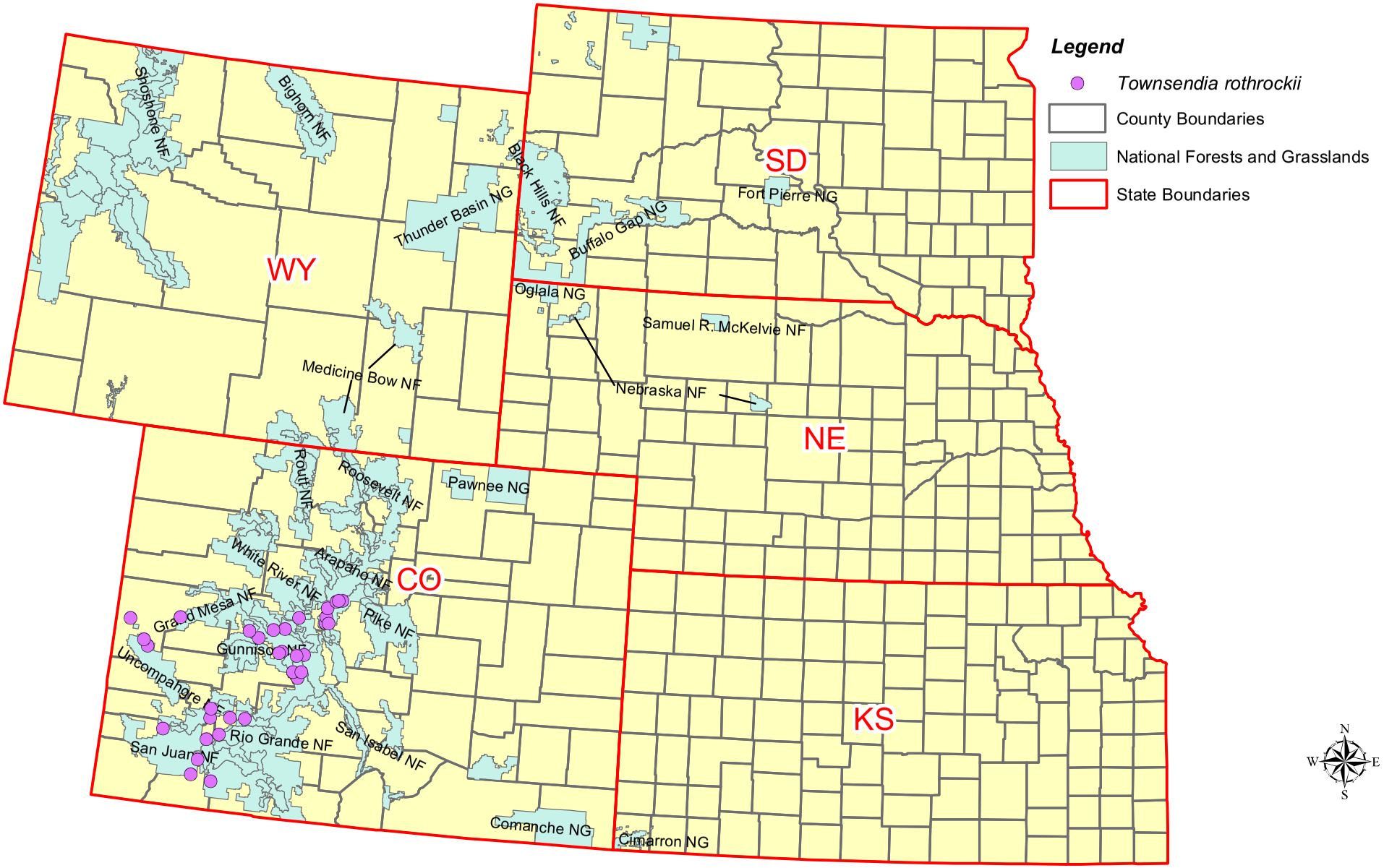


**Figure 1.** Map of U.S. Forest Service Region 2 illustrating distribution of 35 *Townsendia rothrockii* occurrences in Archuleta, Chaffee, Dolores, Gunnison, Hinsdale, Lake, La Plata, Mesa, Ouray, Park, Pitkin, San Juan, and Summit counties, Colorado. Each occurrence may include one to several populations. Refer to document for abundance and distribution information. Sources: Beaman (1957); Colorado Natural Heritage Program, Fort Collins, Colorado (2003); Colorado State University Herbarium, Fort Collins, Colorado (2003); University of Colorado Herbarium, Boulder, Colorado (2003); Rocky Mountain Herbarium, Laramie, Wyoming (2004).

**Table 1.** Information on 35 *Townsendia rothrockii* occurrences in Colorado (USFS Region 2). Includes county, number of occurrences, dates of observation, estimated abundance, land management context, and habitat information. Sources: Beaman (1957), Colorado Natural Heritage Program (2003), Colorado State University Herbarium (2003), University of Colorado Herbarium (2003), Rocky Mountain Biological Laboratory Herbarium (I. Billick personal communication 2004), Rocky Mountain Herbarium (2004).

| County | Date of Observations | Estimated Abundance | Management Area/Ownership | Elevation Range (m) | General Habitat Description | Associated Plant Species |
|---|---|---|---|---|---|---|
| Dolores (1 site) | 1982 | Not available (NA) | USFS San Juan National Forest/ Lizard Head Wilderness | 2,499 | Upper part of oak brush belt | Not available (NA) |
| Gunnison (10 sites) | 1939, 1950, 1956, 1977 | NA | USFS Gunnison National Forest/ Maroon Bells-Snowmass Wilderness/Gothic Research Natural Area | 3,657 to 3,810 | Rocky soil; alpine fellfield; steep south-facing talus, areas of bare soil | *Salix arctica*, *Valeriana capitata*, *Draba nivalis* var. *exigua*, *Physaria* spp. |
| | 1949 | NA | USFS Gunnison National Forest | 3,779 | Fellfield | Not available (NA) |
| | 1955, 1994, 1995 | NA | USFS White River National Forest/ Maroon Bells-Snowmass Wilderness | 3,048 to 3,855 | Subalpine forest and alpine tundra; ridgetop; rocky but with deep soil; bare, pebbly ground; west-facing and slightly south-facing slopes | NA |
| | 1982 | infrequent | USFS Gunnison National Forest | 3,178 | North-northwest exposure, open shrub/ herbaceous area | *Juniperus* spp., *Shepherdia* spp., *Fragaria* spp., *Frasera* spp., *Anemone multifida* |
| | 1985 | NA | USFS Gunnison National Forest | Not available (NA) | Northwest flank of mountain | NA |
| | 1985, 1998 | NA | USFS Gunnison National Forest/ Fossil Ridge Wilderness | 3,597 to 3,871 | Alpine tundra along ridge and on top of mountain; on limestone | NA |
| | 1998 | NA | USFS Gunnison National Forest/ Fossil Ridge Wilderness | 3,444 to 3,536 | Engelmann spruce/subalpine fir krummholtz along ridge | NA |
| | 1951, 1998 | NA | USFS Gunnison National Forest | 3,353 to 3,536 | Outcrop of Belden formation, subalpine meadow; Engelmann spruce/subalpine fir forest between mountains | NA |
| | 1998 | NA | USFS Gunnison National Forest/ West Elk Wilderness | 3,566 to 3,810 | West-facing ridge of peak, alpine tundra | NA |
| | 1998 | NA | USFS Gunnison National Forest/ West Elk Wilderness | 2,499 to 3,597 | Engelmann spruce/subalpine fir krummholtz and alpine tundra on northwest-facing slope | *Picea engelmannii*, *Abies lasiocarpa* |
| Gunnison/Chaffee (1 site) | 1989 | NA | USFS San Isabel National Forest (or USFS Gunnison National Forest) | 3,734 | East-facing slopes, windy dry rocky soil and talus | NA |
| Gunnison/Pitkin (1 site) | 1981, 1984 | NA | USFS Gunnison National Forest | 3,830 to 3,850 | Ridge; granite talus above and south of col (saddle), among rocks; cornice area on east side of ridge; open slopes along roadside, on disturbed ground, mine area, bare soil at col (saddle) | NA |
| Hinsdale (2 sites) | 1878 | NA | USFS Uncompahgre National Forest/Big Blue Wilderness | 3,353 | Not available (NA) | NA |
| | 1998 | NA | USFS Gunnison National Forest | 3,487 to 3,529 | Open spruce forest | *Picea* spp. |
| Hinsdale/ Ouray (1 site) | 1951, 1965 | NA | USFS Uncompahgre National Forest | 3,901 | On steep, rocky southwest-facing slope | NA |
| Lake (1 site) | 1985 | NA | USFS San Isabel National Forest | NA | NA | NA |

**Table 1 (concluded).**

| County | Date of Observations | Estimated Abundance | Management Area/Ownership | Elevation Range (m) | General Habitat Description | Associated Plant Species |
|---|---|---|---|---|---|---|
| La Plata (2 sites) | 1982 | NA | USFS San Juan National Forest/ Weminuche Wilderness | NA | Alpine meadow with limestone outcrops | NA |
| | 1993 | locally abundant | USFS San Juan National Forest/ Weminuche Wilderness | 2,667 | Bare south slopes of red sandstone | NA |
| La Plata/Archuleta (1 site) | 1929 | NA | USFS San Juan National Forest | 3,048 | NA | NA |
| Mesa (4 sites) | 1977 | NA | Colorado BLM | NA | NA | NA |
| | 1981 | NA | USFS Uncompahgre National Forest | 2,438 | Level summit ridge, openings in pine forest with thin red soil and rocks with standing water in springtime | *Pinus* spp. |
| | 1964, 1971, 1981 | scarce | USFS Grand Mesa National Forest | 2,987 to 3,048 | 5 percent slope, south exposure, loam soil, grassland vegetation type; dry rocky streamside, subalpine; lava cliffs | *Festuca* spp., *Agrostis* spp., *Stipa* spp. |
| | 1994 | NA | USFS Uncompahgre National Forest | 2,499 | West-facing slope of Dakota sandstone above creek | *Pinus ponderosa*, *Populus* spp. |
| Park (3 sites) | 1873 | NA | Colorado BLM | 4,115 | NA | NA |
| | 1951 | NA | USFS Pike National Forest/Hoosier Ridge Research Natural Area | 3,810 to 3,840 | South slopes | NA |
| | 1995 | NA | USFS Pike National Forest | 3,750 | Rocky alpine limestone slope | *Geum* spp., *Erigeron* spp. |
| Park/Lake (1 site) | 1990, 1998 | NA | USFS Pike-San Isabel National Forest | 3,642 to 3,658 | Dry, windswept alpine meadow with approximately 50 percent vegetative cover, flat; dry alpine tundra, 50 percent bare ground, limey substrate | *Eritrichium aretioides*, *Oreoxis alpina*, *Polemonium viscosum*, *Rydbergia grandiflora*, *Trifolium dasyphyllum*, *Trifolium nanum* |
| Pitkin (2 sites) | 1955 | NA | USFS White River National Forest/ Maroon Bells-Snowmass Wilderness | 3,977 | Summit of pass | NA |
| | 1960 | NA | USFS White River National Forest/ Collegiate Peaks Wilderness | 3,810 | Always occurring above melting snowbanks on completely bare soil | NA |
| San Juan (4 sites) | 1996 | NA | USFS San Juan National Forest/ Weminuche Wilderness | 3,834 | Limestone outcrop | NA |
| | 2002 | 200+ | USFS Rio Grande National Forest | NA | Gully, late snowmelt area, with barren shaley sides in alpine tundra, naturally disturbed area | NA |
| | 2002 | 100+ | USFS San Juan National Forest | 3,292 | Barren shaley area along highway | NA |
| | 1893 | NA | USFS San Juan National Forest | 3,658 | NA | NA |
| Summit (1 site) | 1970 | NA | USFS Arapaho National Forest | 3,627 | Fellfield areas protruding well below treeline | NA |

## *Existing Regulatory Mechanisms, Management Plans, and Conservation Practices*

The majority of information about *Townsendia rothrockii* is contained within brief descriptions associated with herbarium specimens, often with very little specific location information. Therefore, there is considerable uncertainty regarding the exact location of many sites and occurrence of those populations on USFS lands; inferences are made from location descriptions and mapping exercises. In addition, each location may include several populations over a slope or ridge, and in some cases we considered several records as one occurrence. Of approximately 35 occurrences of *T. rothrockii*, 33 occurrences are thought to be on USFS Region 2 lands, including one occurrence in Arapaho-Roosevelt National Forest, seven occurrences in San Juan National Forest, one occurrence in Rio Grande National Forest, 16 occurrences in Grand Mesa-Uncompahgre-Gunnison National Forest, five occurrences in Pike-San Isabel National Forest, and three occurrences in White River National Forest (**Figure 1**, **Table 1**; Beaman 1957, Colorado Natural Heritage Program 2003, Colorado State University Herbarium 2003, University of Colorado Herbarium 2003, I. Billick personal communication 2004, NatureServe 2004, Rocky Mountain Herbarium 2004). Within these forests, 13 occurrences are thought to be in designated wilderness areas, two occurrences may be in research natural areas, and the remainder of occurrences is on USFS lands that are generally managed for multiple use with an effort to prevent damage to populations of species of special concern (**Table 1**). Thus, the majority of plants are likely on USFS Region 2 lands, and several occurrences are within wilderness and research areas.

Although *Townsendia rothrockii* has been identified as a species of special concern by heritage programs, this species is not currently listed as a USFWS threatened or endangered species or a USFS sensitive species, so there are no specific regulatory mechanisms at the federal level to regulate its conservation. This species may obtain protection from various general conservation strategies designed to protect plants and animals on USFS lands. While managing lands for multiple use, the USFS is directed to develop and implement management practices to ensure that species do not become threatened and endangered (USDA Forest Service 1995). The National Environmental Policy Act (U.S. Congress 1982) requires an assessment of the impacts of any significant USFS projects to natural environments. However, *T. rothrockii* may not be specifically targeted in surveys and evaluations because it is not listed as a sensitive species (D. Erhard personal communication 2003). USFS travel management plans protect rare species by restricting vehicle use to established roads only (USDA Forest Service and Bureau of Land Management 2000), and wilderness areas have restrictions on motorized travel (Office of the Secretary of the Interior 1964). Populations of *T. rothrockii* in research natural areas on USFS Region 2 lands are likely to be protected as part of a national network to preserve representative areas for research, education, and maintenance of biological diversity (USDA Forest Service 1997, S. Olson personal communication 2003).

Existing regulations do not appear to be adequate to conserve *Townsendia rothrockii* over the long term, considering that 1) the abundance and distribution of this species are largely unknown, 2) specific populations may possibly be threatened by human-related and ecological threats, and 3) this species is not considered a sensitive species by the USFS.

## *Biology and Ecology*

### Classification and description

### Systematics and synonymy

*Townsendia rothrockii* Gray ex Rothrock is in the genus *Townsendia* of family Asteraceae (Aster family), order Asterales, and group Dicotyledonae (dicots) of phylum Anthophyta (flowering plants) (NatureServe 2004). The genus *Townsendia* has a relatively small number of species and a fairly limited range; it is comprised of roughly 26 species from central and western North America from Canada to Mexico (Beaman 1954). The type specimen of *T. rothrockii* was collected by Rothrock at South Park (probably Mosquito Pass) in 1873 (U.S. Geological Survey 1878). Larsen (1927) summarized and revised the *Townsendia* genus based on previous work by Gray (1880) and Jones (1893). Beaman (1954, 1957) performed cytotaxonomic and molecular studies to elucidate relationships within the genus. *Townsendia* species are generally difficult to delimit, as a result of hybrids and polyploid apomicts that diverge from species' standards and blur the distinctions between species (Cronquist et al. 1994). Beaman (1957) discovered that *T. rothrockii* apparently consists of both sexually reproducing, diploid populations with a chromosome number of 2n=18 and obligate apomictic, polyploid populations

with a chromosome number of 2n=36. Beaman (1957) did not discuss whether these populations with different ploidy levels may represent different taxa.

This assessment treats this species as *Townsendia rothrockii* Gray ex Rothrock as presented in the PLANTS database (USDA Natural Resources Conservation Service 2002), Integrated Taxonomic Information System database (Integrated Taxonomic Information System 2002), NatureServe database (NatureServe 2004), Catalog of the Colorado Flora (Weber and Wittmann 2000), and Colorado Natural Heritage Program records (Colorado Natural Heritage Program 2003). Common names for *T. rothrockii* include Rothrock's Townsend daisy (USDA Natural Resources Conservation Service 2002), Rothrock townsend-daisy (Colorado Natural Heritage Program 2003, NatureServe 2004), and easter daisy (Weber and Wittmann 1996). The holotype specimen of *T. rothrockii* is housed at the Chicago Natural History Museum (Chicago, IL), and isotypes are housed at the New York Botanical Garden Herbarium (New York, NY) and Gray Herbarium (Cambridge, MA). Within USFS Region 2, additional specimens are located at the University of Colorado Herbarium (Boulder, CO).

### *History of species*

*Townsendia rothrockii* was first collected in 1873 and has been considered in taxonomic treatments of *Townsendia* (Gray 1880, Jones 1893, Larsen 1927, Heiser 1948, Beaman 1954, Beaman 1957). No status assessment or detailed demographic, ecological, or biological studies of this species have been undertaken.

### *Morphological characteristics*

Members of the family Asteraceae are characterized by a head (capitulum inflorescence) with many tiny flowers (florets) crowded onto the receptacle. In many cases, the inflorescence is a radiate head comprised of both ray florets (with strap-like corolla) arranged on the head margin and disc florets (with tubular corolla) in the center of the head. In addition, the heads are subtended by numerous bracts that protect the bud or close over the flower in cold weather (Zomlefer 1994). The genus *Townsendia* is generally distinguished from other members of the Asteraceae family by a convex receptacle, pappus of reduced scales or bristles, two-forked achene hairs, and blue, white, or pink ray flowers (Shultz and Holmgren 1980, Cronquist et al. 1994).

*Townsendia rothrockii* can be identified by its low cushion of dense rosettes; tufts of thick leaves; showy, almost cup-shaped, flower heads with blue rays surrounding yellow disks; and small leaves from 1 to 3.5 centimeters (cm) long (**Figure 2**; Nicholls 2002, Colorado Natural Heritage Program 2003, NatureServe 2004). This species is a rosulate perennial herb up to 2.5 cm tall, with a slender taproot and a short-branched, often woody, caudex (Larsen 1927, Beaman 1957, Nicholls 2002). The entire leaves are green stained with purple, spatulate-obanceolate, conspicuously thickened, and glabrous or sometimes strigose. The leaves are 10 to 35 millimeters (mm) long and 2 to 7 mm wide. The flower heads are nearly sessile or on short peduncles up to 2.7 cm tall. The involucres are 12 to 28 mm wide and 8 to 12 mm high with phyllaries 6 to 9.5 mm long and 2 to 4 mm wide in 4 to 6 series. The phyllaries are glabrous, scarious-margined, red-tinged near the apex, elliptical to broadly lanceolate, and obtuse. The ray-corollas are blue to pale lilac and 8 to 16 mm long and 2 to 3 mm wide, while the disk corollas are yellow, often greenish-tipped, and 3.3 to 4.8 mm long. Both ray and disk achenes are broadly oblanceolate, compressed, ribbed, and lightly pubescent. The ray pappus has squamellae or bristles not over 1.5 mm long, while the disk pappus has approximately 15 to 30 plurisetose, barbellate bristles from 3.2 to 6 mm long (Larsen 1927, Beaman 1957).

*Townsendia rothrockii* can be distinguished from other *Townsendia* species by its conspicuously thickened leaves, short pedunculate or sessile heads, and obovate, ovate, or oblanceolate, obtuse phyllaries, thick involucre bracts lacking scarious margins, a much reduced pappus of ray flowers, and its high-elevation habitat (Harrington 1954, Beaman 1957). Other *Townsendia* species that occur in southwest Colorado include *T. glabella* and *T. leptotes*. *Townsendia glabella* differs from *T. rothrockii* in that *T. glabella* is caulescent or subacaulescent (stems and peduncles are short but definite), leaves are not succulent thickened, phyllaries are lanceolate and acute, and it is known from lower elevations (Weber and Wittmann 1996). Contrary to *T. rothrockii*, *T. leptotes* has hirsute-appressed hairs, scariously margined bracts, large sessile heads (2 to 2.5 cm wide), and linear phyllaries (Weber and Wittmann 1996).

A technical description of *Townsendia rothrockii* is presented in Larsen (1927) and in Beaman (1957). A photograph is available in Weber and Wittmann (1996), and there is currently no published illustration available

for this species; see **Figure 2** for an illustration prepared specifically for this assessment.

## Distribution and abundance

Of the nine *Townsendia* species occurring in Colorado, three are endemic to the state, including *T. rothrockii* (Weber and Wittmann 1996, 2001). Endemism is common in the genus, perhaps as a result of geographic barriers (e.g., mountain ranges), climatic influences (e.g., latitude and elevation), and edaphic preferences (e.g., discontinuous soil types) (Beaman 1957, Shultz and Holmgren 1980, Lowrey and Knight 1994).

**(A)**

Photograph by William Jennings. Reprinted with permission from the photographer.

**(B)**

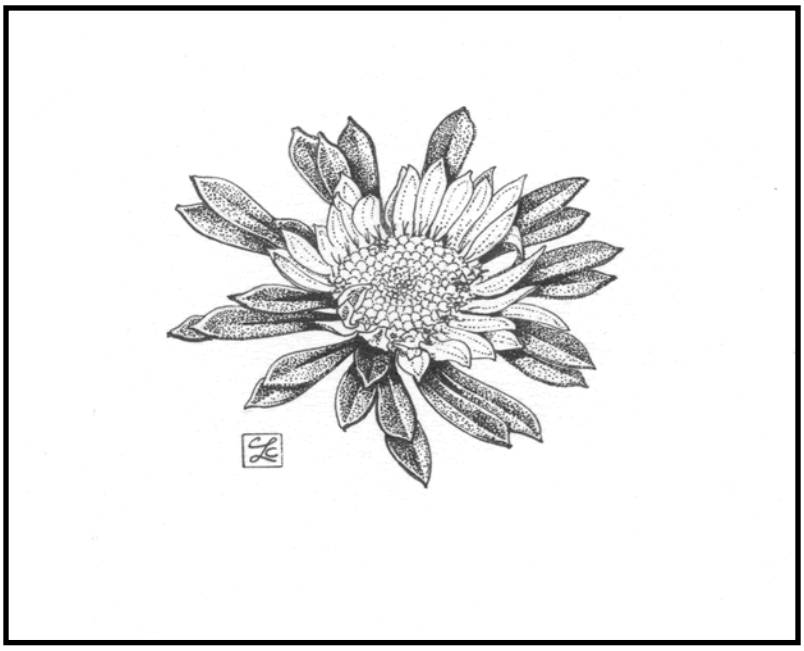

Illustration by Carolyn Crawford. Reprinted with permission from the artist.

**Figure 2.** *Townsendia rothrockii* (A) photograph in its natural habitat, and (B) illustration of the vegetative and reproductive structures.

*Townsendia rothrockii* is a regional endemic species known from approximately 35 occurrences within Archuleta, Chaffee, Dolores, Gunnison, Hinsdale, Lake, La Plata, Mesa, Ouray, Park, Pitkin, San Juan, and Summit counties in Colorado (**Figure 1**, **Table 1**; Beaman 1957, Taylor 1998, Colorado Natural Heritage Program 2003, Colorado State University Herbarium 2003, University of Colorado Herbarium 2003, NatureServe 2004, Rocky Mountain Biological Laboratory 2004, Rocky Mountain Herbarium 2004). The distribution of *T. rothrockii* is largely inferred from brief descriptions on herbarium specimen labels and two element occurrence records from a survey of San Juan County by the Colorado NHP (Colorado Natural Heritage Program 2003, University of Colorado Herbarium 2003). The exact locations of most populations are not known, many populations have not been visited since their discovery in the 1800s or early 1900s, and the current status of all populations has not been assessed. At one location in Pike National Forest, one of the authors of this assessment (W. Jennings) noted several *T. rothrockii* plants were present in 1992 and 1993, but he was unable to find those plants in 1994.

Within USFS Region 2 lands, *Townsendia rothrockii* occurs in Grand Mesa-Uncompahgre-Gunnison National Forest, Arapaho-Roosevelt National Forest, Pike-San Isabel National Forest, Rio Grande National Forest, San Juan National Forest, and White River National Forest (**Figure 1**, **Table 1**). *Townsendia rothrockii* was not included in a summary of plants of special concern on Pike-San Isabel National Forest (Kettler et al. 1993), but this species is found on that national forest. Although the PLANTS database (USDA Natural Resources Conservation Service 2002) and Kartesz (1999) note that the range of this species includes New Mexico, other sources suggest that these records are anecdotal (i.e., not based on actual specimens) and are likely in error (New Mexico Rare Plant Technical Council 2003, R. Sivinski personal communication 2003, NatureServe 2004).

Abundance estimates for *Townsendia rothrockii* are lacking, with only brief descriptions for five populations, including "100+," "200+," "scarce," "infrequent," and "locally abundant" (Colorado Natural Heritage Program 2003, University of Colorado Herbarium 2003) (**Table 1**). Thus, the current abundance of this species on USFS Region 2 lands has not been adequately assessed.

## Population trends

There are no data on population trends for *Townsendia rothrockii*. Population sizes have not been estimated, and multi-year population or demographic monitoring has not been initiated for any site.

## Habitat characteristics

Habitat characteristics have not been extensively described for *Townsendia rothrockii*; all available notes from herbarium specimen labels and NHP element occurrence records are reproduced in **Table 1**. *Townsendia rothrockii* is a perennial forb inhabiting a variety of microhabitats in montane, subalpine, and alpine habitats from 2,438 to 4,115 meters (m) (8,000 to 13,500 feet [ft]) in the mountains of central to southwestern Colorado (**Table 1**; Beaman 1957, Colorado Natural Heritage Program 2003, Colorado State University Herbarium 2003, University of Colorado Herbarium 2003, NatureServe 2004, Rocky Mountain Herbarium 2004). This species has been reported growing in alpine fellfields, krummholtz, subalpine meadows, oak brush, grasslands, shrub/herbaceous areas, talus slopes, forest openings, high plateau ridgetops, mountain passes, late-snow and cornice areas, limestone outcrops, rocky streamsides, disturbed mine and roadside areas, bare sandstone slopes, lava cliffs, and summit ridges (**Table 1**; Weber and Wittmann 1996, Colorado Natural Heritage Program 2003, Colorado State University Herbarium 2003, University of Colorado Herbarium 2003, NatureServe 2004, Rocky Mountain Herbarium 2004). Plant species associated with *T. rothrockii* include forbs, grasses, shrubs, and trees, such as *Abies lasiocarpa*, *Agrostis thurberiana*, *Anemone multifida*, *Draba nivalis* var. *exigua*, *Eritrichium aretioides*, *Festuca thurberi*, *Frageria* spp., *Frasera* spp., *Juniperus* spp., *Oreoxis alpina*, *Physaria* spp., *Pinus* spp., *Pinus ponderosa*, *Polemonium viscosum*, *Populus* spp., *Quercus* spp., *Rydbergia grandiflora*, *Shepherdia* spp., *Stipa* spp., *Trifolium dasyphyllum*, *Trifolium nanum*, and *Valeriana capitata* (**Table 1**; Beaman 1957, Colorado Natural Heritage Program 2003, Colorado State University Herbarium 2003, University of Colorado Herbarium 2003, NatureServe 2004, Rocky Mountain Herbarium 2004). Not enough information is available to describe vegetation communities associated with *T. rothrockii* using the classifications of Grossman et al. (1998).

Acaulescent *Townsendia* species often require highly specialized edaphic conditions, such as sparsely vegetated limestone, sandstone, or shale rubble (Beaman 1957). Specifically, Beaman (1957) found several populations of *T. rothrockii* growing in microhabitats consisting of red sandstone fragments where the individuals flowered under the fragments as the snow melted away. Beaman (1957) hypothesized that this species may be edaphically specialized to areas with sandstone fragments, although individuals can survive in other microhabitats as well (Beaman 1957). *Townsendia rothrockii* has since been found on a variety of substrates, such as rocky soils, steep talus, dry rocky soil, granite talus, lava cliffs, limestone outcrops, red sandstone, thin red soil, loam soil, and limey substrates (Colorado Natural Heritage Program 2003, Colorado State University Herbarium 2003, University of Colorado Herbarium 2003, NatureServe 2004, Rocky Mountain Herbarium 2004). Based on extrapolation from geologic maps, the substrates in these areas could include limestones and formations containing limestone beds (e.g., Leadville, Maroon, Minturn, and Niobrara formations), sandstones (e.g., Wingate Formation), shales (e.g., Mancos Formation), granites, and basaltic volcanics (Tweto 1979). The reported slopes ranged from flat to steep, of south, north, northwest, and east-facing aspects (**Table 1**). The only records of ground cover ranged from 50 percent vegetation cover to areas of bare soil to completely bare soil (**Table 1**; University of Colorado Herbarium 2003).

## Reproductive biology and autecology

Although the reproductive biology of *Townsendia* species has been the subject of preliminary investigative study (Beaman 1954, Beaman 1957, Thompson 2001), details concerning the reproductive biology of *T. rothrockii* are largely inferred or unknown. In this and subsequent sections, we summarize available observations of *T. rothrockii* as well as present information from other *Townsendia* species endemic to USFS Region 2 or adjacent states. These comparisons are not meant to imply that *T. rothrockii* necessarily reproduces in a similar manner, but they may help to elucidate *potential* reproductive mechanisms for this species and suggest avenues for future research.

### *Reproduction*

*Townsendia rothrockii* produces an inflorescence (head, capitulum) with many small flowers (florets). The inflorescence is a radiate head comprised of both ray florets (with strap-like corolla) arranged on the head margin and disc florets (with tubular corolla) in the center of the head. The ray florets are either pistillate (female) or sterile, and the disc florets are staminate (male) or perfect (male and female) (Zomlefer 1994). This species starts forming buds in the winter and begins flowering as the snow melts in the late spring and early summer from March to May (Colorado Natural Heritage Program 2003, Willard Bay Gardens 2003). Flowering individuals have been photographed in July and August; the timing of flowering likely fluctuates from year to year depending on snowmelt.

The genus *Townsendia* is characterized by species and populations exhibiting an array of hybridization, polyploidy, and apomixis (asexual reproduction through seeds) (Beaman 1954, 1957). The role of these processes in the speciation of *Townsendia* and evolution of *T. rothrockii* is not fully understood and has resulted in a genus with complex interrelationships (Beaman 1954, 1957). *Townsendia rothrockii* apparently consists of both sexually reproducing, diploid populations with a chromosome number of 2n=18 and obligate apomictic, polyploid populations with a chromosome number of 2n=36 (Beaman 1957). Apomixis in *T. rothrockii* was demonstrated when diploid plants produced few seeds when cross-pollination was prevented, whereas non-cross-pollinated polyploid plants and plants lacking stamens and styles produced copious amounts of viable seed (Beaman 1954). Of the six populations identified by 1957, Beaman (1957) noted that four populations were apomictic. The extent of sexual or asexual reproduction in all currently known populations of *T. rothrockii* has not been determined, and the genetic and environmental factors influencing these processes have not been identified.

### *Life history and strategy*

There have been no studies on the life history, demographic rates, fecundity, or longevity of *Townsendia rothrockii*. It is a perennial forb growing with a slender taproot in alpine habitats. This species may possibly be considered an s-selected, or stress-tolerant, species because of its perennial life history, ability to withstand relatively harsh and unproductive conditions, and capability to access resources with a taproot (Grime 1979, Barbour et al. 1987). The hypothesized life cycle of this perennial plant is depicted in **Figure 3**.

Many alpine plants share similar strategies and adaptations to harsh environmental conditions and a short growing season (Grime 1979, Zwinger and Willard 1996). Many alpine plants, including *Townsendia rothrockii*, have a perennial life history because the short growing season precludes annual plants from

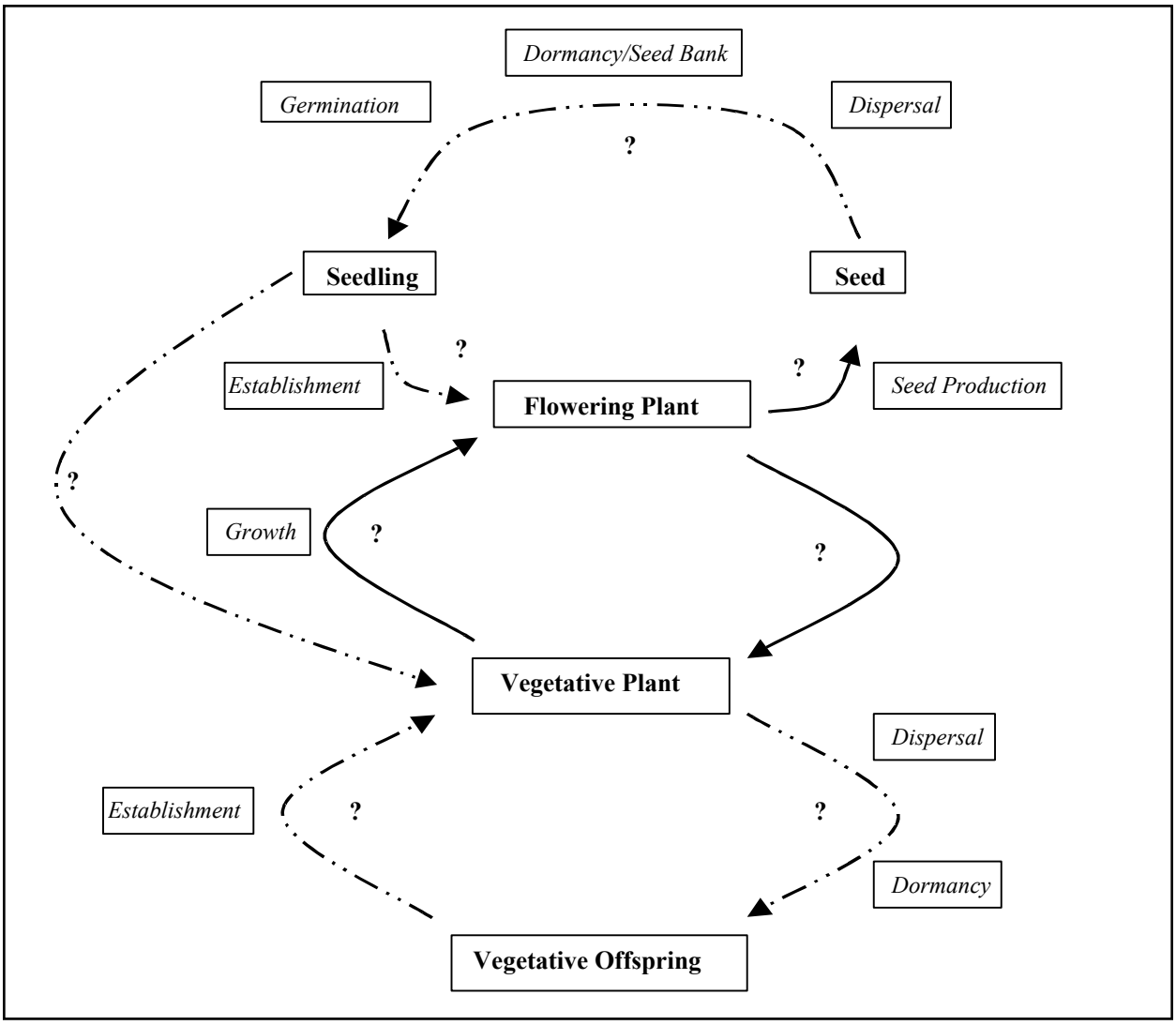


**Figure 3.** Schematic representation of the hypothesized life cycle of *Townsendia rothrockii*. Dotted lines indicate juvenile phases of the life cycle and solid lines indicate mature phases of the life cycle. Reproduction by seed may occur by sexual or asexual (apomixis) processes. Extent of seed or vegetative reproduction is unknown for this species. Rates of growth, dispersal, and seed production are also unknown (indicated by "?"). Figure adapted from Grime (1979).

producing stems, leaves, flowers, and fruit in a few months. Using food reserves stored underground in roots allows alpine perennials to flower early in the season and take advantage of the short summer heat to ripen seeds. In addition, many alpine plants have extended growth patterns where it may take many years for a plant to develop, produce buds, and eventually flower and set seed.

The morphology of *Townsendia rothrockii* and other alpine plants also helps to increase survival in harsh conditions such as cold temperatures, desiccating winds, intense solar radiation, and low moisture (Grime 1979, Zwinger and Willard 1996). These conditions are especially intense in *T. rothrockii* habitat, which can include fellfields, boulder outcrops, and gravelly slopes with dry soils and sparse plant cover. When growing in exposed areas, this species must overcome environmental obstacles such as erosion/deposition, high water runoff, and intense solar radiation and wind. The low growth and small size of *T. rothrockii* presumably keeps individuals out of harsh winds, reduces plant tissue growth needs, creates less distance to transport water, allows interception of both solar radiation and ground-reflected radiation, and affords protection to the inner parts of the plant. Many alpine plants, including *Townsendia* species, also grow extensive roots in order to anchor them in strong winds and loose substrates

and to exploit precious moisture (Zwinger and Willard 1996, Nicholls 2002).

### *Pollinators and pollination ecology*

As discussed above, *Townsendia rothrockii* is known to be apomictic (i.e., not relying on pollination), but sexual diploid populations have also been recorded (Beaman 1957, University of Colorado Herbarium 2003), and these populations presumably rely upon cross-pollination. However, pollination biology and specific pollination mechanisms for *T. rothrockii* have not been studied.

In general, members of the Asteraceae family are well equipped to attract pollinators and disperse pollen. The showy inflorescences of these aster species attract pollinators and allow many flowers to be visited in a short time. In addition, unique aster flower adaptations cause nectar and pollen to be easily accessed and dispersed by pollinators (Zomlefer 1994). Bumblebees, solitary bees, butterflies, flies, and other insects are common pollinators in mountainous ecosystems (Zwinger and Willard 1996).

Important issues related to the pollination of rare plants that have yet to be researched for *Townsendia rothrockii* include the extent of asexual and sexual reproduction, identity of effective pollinators, the effect of plant density on pollination, genetic implications of pollination, and effect of environmental fluctuations on pollination.

### *Dispersal mechanisms*

Details of seed dispersal mechanisms in *Townsendia rothrockii* have not been studied. *Townsendia rothrockii* flowers and seeds are close to the ground where wind (common at high elevations), water movement (e.g., sheets of rain, snow melt off), soil movement (e.g., erosion), and animal vectors (e.g., small mammals, ants) could possibly disperse the seeds. This species has bristles on the achenes that could facilitate dispersal (Zomlefer 1994). Presumably, dispersal success of *T. rothrockii* may depend on wind and precipitation patterns, substrate characteristics, animal activities, topographic heterogeneity, and availability of suitable "safe" sites.

### *Seed viability and germination requirements*

No information is available concerning the fertility, seed viability, and germination requirements of *Townsendia rothrockii* in natural environments. *Townsendia* species are extensively grown in cultivation and notes on cultivated *T. rothrockii* suggest that this species is easy to grow in pots, troughs, or rock gardens, prefers full sun and gravelly soils, and reseeds itself (Nicholls 2002, Edge of the Rockies Native Seed 2003, Willard Bay Gardens 2003).

### *Phenotypic plasticity*

Phenotypic plasticity is demonstrated when members of a species vary in height, leaf size, flowering time, or other attributes, with change in light intensity, latitude, elevation, or other site characteristics. *Townsendia rothrockii* occurs at a range of elevations and in a variety of topographical contexts, and it is possible that flowering times vary with these different microenvironments. As discussed previously, flowering times are also probably closely linked with the timing of snowmelt, which can vary from year to year (Beaman 1957).

### *Cryptic phases*

No information regarding cryptic phases of *Townsendia rothrockii* is available. Seed dormancy can be an important adaptation for plant populations to exploit favorable conditions in a harsh environment (Kaye 1997). It is not known whether a persistent seed bank exists or what the extent of seed dormancy is for *T. rothrockii*. Details of seed longevity, patterns of seed dormancy, and factors controlling seed germination for *T. rothrockii* have not been studied.

### *Mycorrhizal relationships*

The existence of mycorrhizal relationships with *Townsendia rothrockii* was not reported in the literature.

### *Hybridization*

There is evidence of extensive hybridization within the genus *Townsendia* (Beaman 1954), but hybridization specifically with *T. rothrockii* has not been reported. The role of hybridization in the evolution of this species is also unknown.

## Demography

Little is currently known about population demographics in *Townsendia rothrockii*. Research on other *Townsendia* species, where available, may provide insights into some of the ecological, spatial, and genetic considerations for *T. rothrockii* demography. Refer

to **Figure 4** and **Figure 5** for envirograms outlining resources and malentities potentially important to *T. rothrockii*. An envirogram is a schematic diagram, first introduced by Andrewartha and Birch (1984) for animal species, that depicts relationships between a target organism and environmental conditions. The centra are the main categories (i.e., resources and malentities) that directly affect the target species, and the web outlines factors that indirectly influence the centra. The web depicts the most distal to most proximal factors using linear, one-way branches. Because there is a paucity of ecological information about this species, the envirograms outline hypothesized resources and malentities that are *potentially* important for *T. rothrockii*. Additional information would be needed to create more comprehensive and specific envirograms.

### *Life history characteristics*

There is no information regarding population parameters or demographic features of *Townsendia rothrockii*, such as metapopulation dynamics, life span, age at maturity, recruitment, and survival.

**Life cycle diagram and demographic matrix.** A life cycle diagram is a series of nodes that represent the different life stages connected by various arrows for vital rates (i.e., survival rate, fecundity). Demographic parameters, such as recruitment and survival rates, are not currently available for *Townsendia rothrockii*, and so there are no definitive data regarding the vital rates that contribute to species fitness. Although stage-based models based on population matrices and transition probabilities can be used to assess population viability (Caswell 2001), adequate quantitative demographic data are needed for input into the model. For *T. rothrockii*, the stages that could potentially be incorporated into a demographic matrix include seed, seedling, vegetative individuals, and reproductive adults (**Figure 3**).

Presumably, seeds of *Townsendia rothrockii* are dispersed to suitable locations. The probability of germination and subsequent establishment depends on the longevity of these propagules and whether appropriate environmental conditions exist for germination and growth. Seeds that germinate can grow into seedlings, assimilate resources, and mature into reproductive individuals. Growth rates may be influenced by the intensity and frequency of disturbance and availability of resources, such as space, light, moisture, and nutrients. Successful seed set will depend on the rate of pollen and ovule formation, pollination, fertilization, and embryo development. Fecundity rates depend on the production of seeds and the percentage of those seeds that survive to germination in subsequent years.

**Population viability analysis.** In order to initiate a population viability assessment for *Townsendia rothrockii*, the rates of germination, fecundity, survival, and other important parameters require additional study using long-term monitoring plots.

### *Ecological influences on survival and reproduction*

Germination, growth, seed production, and long-term persistence of *Townsendia rothrockii* most likely depend on a range of ecological influences over many years, including climatic fluctuations (e.g., water availability, erosive factors), microsite conditions (e.g., nutrients, light, water availability), herbivory, disturbance patterns, seed dispersal vectors, interspecific competition, seed predation, and pollinator activities. These factors are summarized in an envirogram outlining resources potentially important to *T. rothrockii* (centrum) and the indirect variables affecting those centrum factors (**Figure 4**). For example, seed dispersal could be related to animal activities or weather variables (e.g., wind and water movement). There is little information on the capabilities of *T. rothrockii* to disperse, colonize, and establish new populations around the landscape. The establishment of new populations most likely depends on barriers to dispersal and the availability of suitable germination sites and conditions. The rate of population growth could also be influenced by factors that would affect sexual reproduction, such as pollinator limitation.

It is also unclear what type, size, intensity, or frequency of disturbance regime is important for *Townsendia rothrockii*. Disturbances in mountainous environments can include erosion/deposition, fire, blowdowns, frost heaving, wind-scouring, herbivory, environmental fluctuations, and human influences (Zwinger and Willard 1996). These disturbances could either create suitable habitat throughout a landscape or directly impact an existing population, depending on intensity and disturbance location. For example, *T. rothrockii* populations on talus slopes could be extirpated by erosion or rockslide, or new suitable habitat could be created for future populations. *Townsendia rothrockii* occurs on old mining roads that were in use approximately 100 years ago; this species appears to take advantage of the exposed substrates and reduced competition at these previously disturbed sites (B. Johnston personal communication 2003). Most populations of *T. rothrockii* are unlikely to be directly

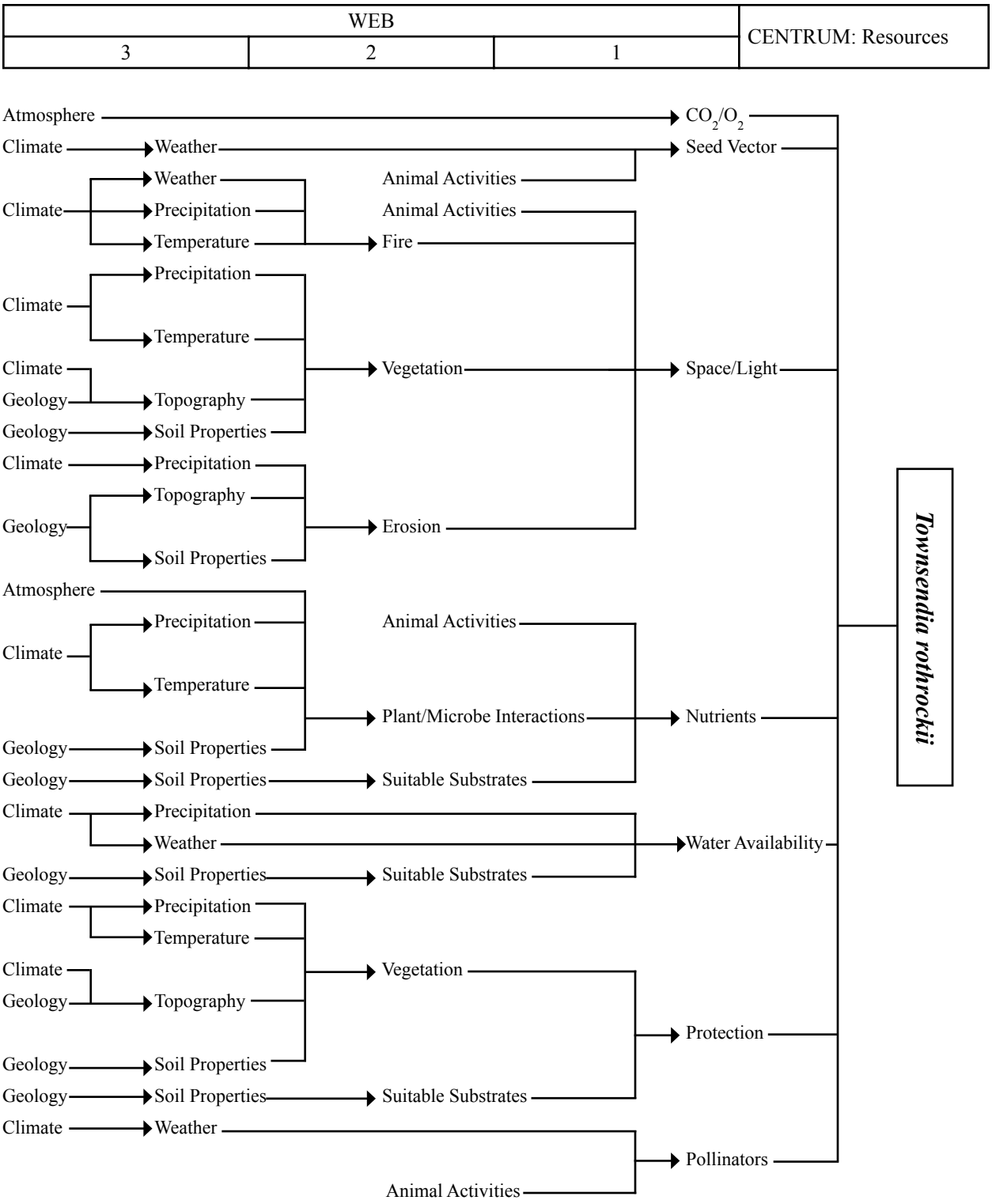


**Figure 4.** Envirogram outlining potential resources for *Townsendia rothrockii*. An envirogram depicts direct and indirect factors that may influence a species. The centrum includes the most proximate factors, and the web includes more distal factors.

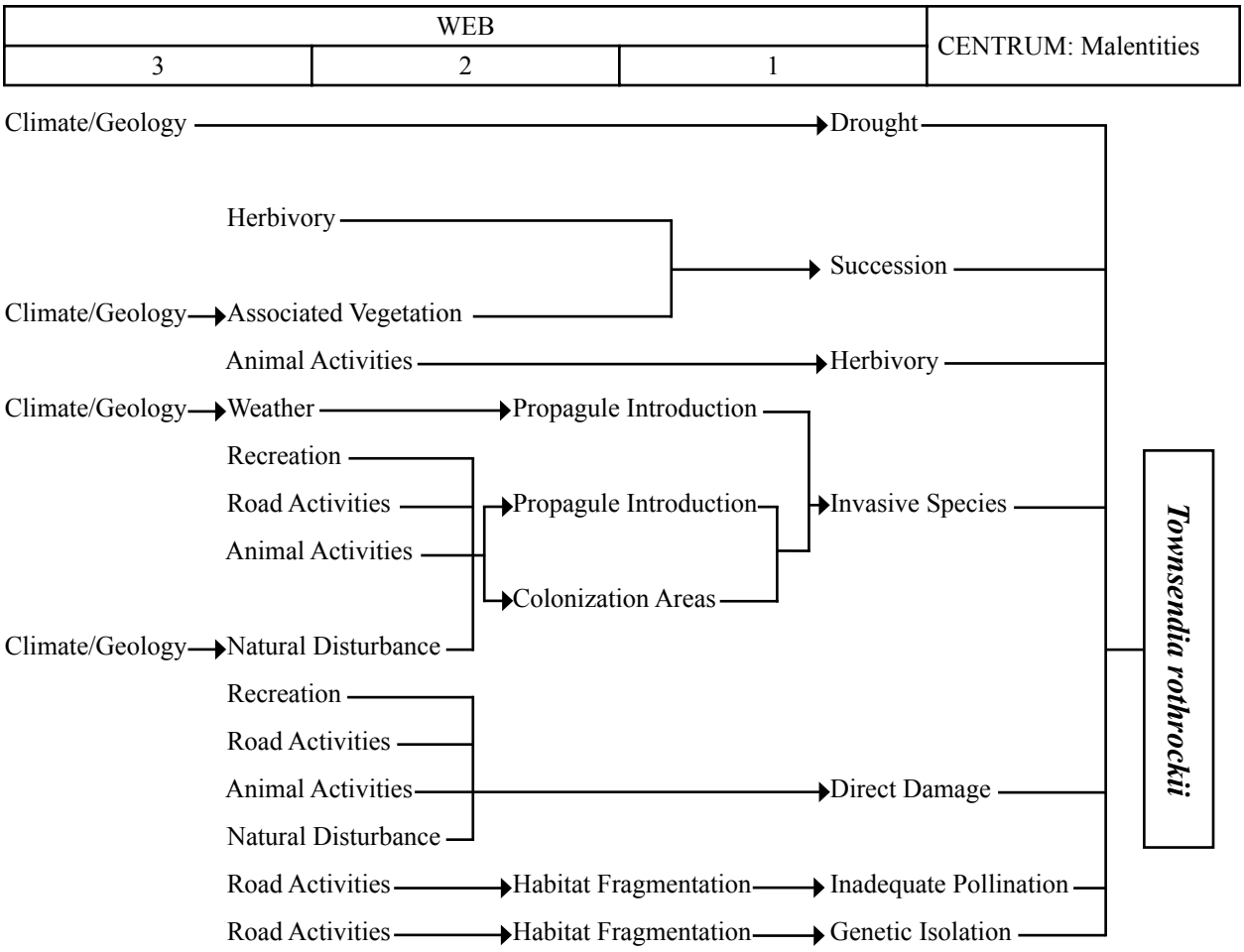


**Figure 5.** Envirogram outlining malentities to *Townsendia rothrockii*. An envirogram depicts direct and indirect factors that may influence a species. The centrum includes the most proximate factors, and the web includes more distal factors.

affected by blowdowns or fire because they generally occur above treeline in rocky areas with minimal ground fuels. However, *T. rothrockii* is also known from several populations below treeline and potentially could be affected by the direct or indirect effects of fire in those areas of its range. It appears that *Townsendia* species are sun-loving species, and other *Townsendia* species have benefited from thinning and prescribed burning, which reduce competition and shading from the overstory and litter (B. Johnston personal communication 2003).

### *Spatial characteristics*

The spatial distribution of *Townsendia rothrockii* at local and regional scales has not been studied. This species appears to be scattered over a variety of elevations, habitat types, and drainages throughout central and southwestern Colorado. The scattered distribution may represent actual ecological or dispersal barriers perhaps as a result of highly variable topography and substrates, or alternatively, it may reflect "holes" in the distribution due to incomplete inventory efforts. Throughout its range, *T. rothrockii* is found on a variety of different substrates, but it often occurs in a localized edaphic situation (Beaman 1957). Metapopulations likely occur where *T. rothrockii* occupies several sites in a local area with suitable substrates, such as on a ridge or slope. In an analysis of substrate and elevation information performed by the authors of this assessment, it appears that when this species occurs above about 3,140 m (10,300 ft), it is usually on calcareous substrates, and below 3,140 m (10,300 ft) elevation, this species usually occurs on volcanic or shaley substrates. These characteristics are also related to geographic distribution, as the sites in the Mosquito Range of central Colorado (e.g., occurrences in Lake and Park counties) tend to be high elevation limestone sites and the sites in the Grand Mesa area and San Juan Mountains of southwestern Colorado (e.g., Mesa and San Juan counties) tend to be

volcanics, sandstones, and shales at lower elevations. The ecological, biogeographical, genetic, or taxonomic implications of different substrate tolerances of *T. rothrockii* are not known. This species may have a wide ecological amplitude and is not generally limited by substrate qualities. Geographical barriers and dispersal ecology may be very important features affecting the spatial distribution of this species. It is also possible that these two substrate classes may actually represent two different taxonomic groups. The genetic variability between populations of this species is not known. The spatial configuration of metapopulations or the extent to which gene flow occurs between local and distant populations is unknown for *T. rothrockii*. Characteristics that could influence the spatial distribution of this species may include habitat availability, seed dispersal patterns, competition with other vegetation, landscape and microsite heterogeneity, and disturbance patterns.

### *Genetic characteristics and concerns*

Genetic concerns, such as the amount of genetic variability between and within the occurrences, have not been studied for *Townsendia rothrockii*. In addition, the effects of polyploidy and apomixis on the genetic status and subsequent evolution of this species are unknown. For example, the genetic variability of a polyploid asexual population could differ depending on whether there was a single founder, multiple founders, or occasional asexual reproduction (Thompson 2001). Obligate apomicts may be less likely to change or adapt as a result of sexual recombination events and selective forces, but the genetic status may be more stable over time and polyploids can enrich the total gene pool of a species (Beaman 1957, Thompson 2001). Thompson (2001) is currently studying the genetic consequences of polyploidy in *T. hookeri*, a species with both sexual diploid and apomictic populations. Issues related to gene flow, inbreeding, and genetic isolation could affect the demography, ecology, management considerations, and long-term persistence for *T. rothrockii*. For example, it is possible that populations with differing ploidy levels may actually represent different taxa. Assessing the genetic variability of populations is also important for establishing conservation plans to protect genetic diversity and for designing reintroduction plans.

### *Factors limiting population growth*

There is insufficient knowledge about *Townsendia rothrockii* to determine what factors limit population growth. Population growth or establishment of *T. rothrockii* could possibly be limited by competition with other species (e.g., invasive species), inadequate genetic variability for long-term persistence, ineffective pollination, or reduced habitat availability as a result of human-related changes or environmental fluctuations. The rate at which colonization and establishment of new populations occurs is unknown.

## Community ecology

### *Herbivores and relationship to habitat*

The extent or effects of herbivory on *Townsendia rothrockii* are unknown. In addition, the exact locations of this species are largely unknown, and the details of management activities are difficult to ascertain. Sheep grazing occurs in Rio Grande National Forest possibly near one *T. rothrockii* site, but the possible direct or indirect effects of sheep on this plant are unknown (D. Erhard personal communication 2003). Because *T. rothrockii* tends to inhabit bare, exposed, or loose sites, it may not be targeted by livestock. In addition, it is likely that its small size and prostrate growth causes *T. rothrockii* to be missed by grazers and browsers. Grazing allotments do exist at other areas with *T. rothrockii* populations (e.g., Boreas Pass, Conundrum Pass, Molas Pass), but these allotments have been vacant for several years and it is not expected that they will be used in upcoming years (K. Giezentanner personal communication 2003, S. Olson personal communication 2003, J. Redders personal communication 2003).

*Townsendia rothrockii* could also possibly be affected by grazing or trampling disturbances by native herbivores, such as large ungulates (e.g., elk, deer, bighorn sheep, mountain goats), small mammals (e.g., pika, marmots, gophers, hares), or insects (e.g., ants, beetles). The palatability of *T. rothrockii* to herbivores is largely unknown. Authors of this assessment failed to find indication of herbivory of *T. rothrockii* individuals in the field or in photographs.

### *Competitors and relationship to habitat*

The interactions of *Townsendia rothrockii* within the plant community are not well known. The successional or competition dynamics in these habitats and the full range of tolerances of *T. rothrockii* have not been studied. The severity of competition for resources is not known but is likely to be minimal at sparsely vegetated, harsh, rocky sites and more significant in grassy meadows. Plants co-occurring with *T. rothrockii* could compete for available resources or possibly facilitate soil stabilization and the accumulation of organic material and moisture. Succession tends to be a slow process in alpine environments, but historical

evidence demonstrates that, over a long time, cushion plants of fellfields can be outcompeted by taller grasses and sedges to form alpine meadows (Zwinger and Willard 1996). The characteristics of the natural fire regime and the response of *T. rothrockii* to fire have not been studied. Fuel loads in subalpine and alpine habitats are minimal and patchily distributed, resulting in spot fires with low temperatures that would not kill deep-rooted perennials. Fire may play a larger role for *T. rothrockii* plants at below-treeline sites rather than plants at late-lying snow areas above treeline.

There are no reports of exotic species specifically affecting *Townsendia rothrockii*. The introduction of exotic species can be a secondary effect of trail and road construction, and in some instances, exotic species can outcompete or replace native plants by using space, nutrients, and water. Potential montane, subalpine, and alpine non-native invasive plant species in Colorado include *Cirsium arvense* (Canada thistle), *Carduus nutans* (musk thistle), *Chrysanthemum leucanthemum* (ox-eye daisy), *Linaria vulgaris* (yellow toadflax), *Matricaria perforata* (scentless chamomile), *Phleum pretense* (timothy grass), *Taraxacum officinale* (common dandelion), and *Trifolium repens* (white clover) (Chumley 1998). The extent of non-native plant invasions near existing populations of *T. rothrockii* is not known. The threat of exotic species to *T. rothrockii* most likely differs depending on geographic location, elevation, distance from weed hotspots (e.g., roads and trails), dispersal mechanisms, and other factors related to disturbance factors.

### *Parasites and disease*

Evidence for parasites or diseases on *Townsendia rothrockii* has not been reported.

### *Symbiotic interactions*

Insect pollination of flowering plants is an example of an important symbiotic interaction. Plants lure insects to a pollen or nectar reward, and the insects carry pollen to other flowers, thus, helping to cross-fertilize. Specific details concerning pollination ecology of *Townsendia rothrockii* are largely unknown. The positive interactions between other associated plant or microbial species and *T. rothrockii* are also unknown.

### *Habitat influences*

*Townsendia rothrockii* does not appear to be edaphically specialized to one substrate type over its entire range, but it does appear to occur locally on exposed limestone, granitic, shale, sandstone, or volcanic substrates. Within areas of suitable substrates, *T. rothrockii* apparently inhabits a wide variety of microhabitats with sparse vegetation and exposed soils, ranging from rocky outcrops to talus slopes to fellfields (Colorado Natural Heritage Program 2003, University of Colorado Herbarium 2003). The availability and quality of suitable microsites may depend on heterogeneity in parent material, elevation, topography, environmental fluctuations, disturbance factors, and competition with other species.

## CONSERVATION

### *Threats*

Threats to the long-term persistence of *Townsendia rothrockii* in USFS Region 2 are mostly unknown because of the lack of species understanding and research. The information presented in this section is primarily based on information provided in element occurrence records and personal communications with forest botanists (D. Erhard personal communication 2003, K. Giezentanner personal communication 2003, B. Johnston personal communication 2003, S. Olson personal communication 2003, J. Redders personal communication 2003).

*Townsendia rothrockii* populations and habitat throughout its range, including USFS Region 2 lands, could potentially be threatened by a variety of human-related activities (e.g., recreation) or environmental changes (e.g., global climate changes, invasive species introduction). These factors are summarized in an envirogram outlining malentities potentially important to *T. rothrockii* (centrum) and the indirect variables affecting those centrum factors (**Figure 5**). The specific threats and the intensity of those threats will vary from population to population. Estimating the numbers of populations potentially threatened by certain activities (e.g., trail or road activity) is associated with considerable uncertainty because the spatial juxtaposition of *T. rothrockii* individuals with potential disturbances is not known. For example, a population may be "near a road" and could subsequently suffer intense impacts from direct trampling, road dust, associated erosion and deposition, or alternatively it could suffer minimal effects if the road is not heavily traveled or the population is some distance from the road or above the road on a cliff. Direct impacts could either damage the existing individuals or reduce reproductive success, available habitat, establishment of new populations, or other factors important for long-term persistence of the species.

Possible human-related threats to *Townsendia rothrockii* could include motorized and non-motorized recreation, road and structure construction, erosion and sedimentation related to roads, livestock grazing, exotic species invasion, small-scale mining, or any changes to natural disturbance regimes. The extent of these activities near existing populations of *T. rothrockii* or in suitable *T. rothrockii* habitat is unknown. Overutilization of *T. rothrockii* for educational, scientific, or horticultural purposes is also unknown. Although old disturbances, such as the creation of mine roads, may have resulted in suitable habitat for *T. rothrockii*, it is also possible that current disturbances associated with roads and trails may threaten existing populations of this species. There are numerous two-track roads and trails running through USFS lands with populations of *T. rothrockii* or potential habitat for *T. rothrockii*. Motorized vehicles, mountain bikers, and hikers have the potential to trample *T. rothrockii* populations occurring in accessible habitats. Any plants found along roadsides and at popular pass areas could be directly damaged by vehicles pulling off the road and foot traffic. Although off-highway vehicle use is generally restricted to existing roads and trails by travel management plans and is prohibited in wilderness areas (D. Erhard personal communication 2003, K. Giezentanner personal communication 2003, B. Johnston personal communication 2003, S. Olson personal communication 2003, J. Redders personal communication 2003), there still might be impacts of off-highway vehicle use through prohibited off-trail use, erosion/sedimentation, and introduction of non-native seeds. Roads can be associated with significant erosion and sedimentation issues for the surrounding landscape that could affect any populations of *T. rothrockii* found downslope from roads. One element occurrence record noted that this species occurs on a pass with off-highway vehicle use, and the pass is a popular place to stop, but the site did not appear to be impacted (Colorado Natural Heritage Program 2003). One of the authors of this assessment (W. Jennings) observed this plant several feet from the side of a rough two-track road that receives little traffic, and he noted that neither the site nor the plant appeared to be impacted. Roads and trails are also often associated with the spread of invasive plants that could compete with *T. rothrockii* for resources. *Townsendia rothrockii* populations on rocky outcrops, talus slopes, and other inaccessible alpine habitats may be less impacted by recreational activities and spread of invasive plants. It is unknown what effect winter snowmobile use may have on this species (B. Johnson personal communication 2002). *Townsendia rothrockii* can occur in areas with late-lying snowfields, and intense snowmobile activity could possibly affect snowmelt timing and patterns.

Surface-disturbing activities, such as natural resource development and structure construction, could damage known populations and potential habitat for *Townsendia rothrockii*. Any mining activity, road construction, or road maintenance that causes soil disturbance in areas with established populations of *T. rothrockii* could negatively impact this species (B. Johnston personal communication 2002). Historical mining in the Mosquito Range occurred on deposits in the Leadville Limestone Formation, but these mines tended to be small by modern standards. There is little, if any, mining or exploration currently occurring. Existing populations of *T. rothrockii* adjacent to or downslope from a major highway or forest road could be impacted by road expansion or maintenance. In general, surface disturbances in alpine habitats can take much longer to restore (Zwinger and Willard 1996). The extent of surface disturbing activities at *T. rothrockii* sites on USFS lands is unknown. At least 15 occurrences may be found in USFS wilderness areas or research natural areas, where motorized travel and construction are prohibited.

*Townsendia rothrockii* generally occurs at high elevations on loose slopes and other areas with exposed substrates and low productivity. Therefore, it would likely not be affected by thinning, timber harvest, or prescribed burning activities. In addition, fire typically does not play a large role in alpine ecosystems (B. Johnston personal communication 2002). Populations that occur below timberline could possibly be affected by these activities (D. Erhard personal communication 2003, K. Giezentanner personal communication 2003, B. Johnston personal communication 2003, S. Olson personal communication 2003, J. Redders personal communication 2003). However, *T. rothrockii* appears to occupy openings within forested areas and other exposed areas. This species may benefit from land management activities that open up the overstory and reduce competition within its habitat (B. Johnston personal communication 2003).

Environmental and biological threats to populations of *Townsendia rothrockii* include environmental fluctuations, genetic isolation, succession, herbivory/grazing, inadequate pollination, global climate changes, or changes to the natural disturbance regime. Disturbances and environmental fluctuations can either create suitable habitat throughout a landscape or directly impact an existing population, depending on frequency, intensity, size, and location. *Townsendia rothrockii* may rely on wind and water erosion to reduce competition and to maintain available substrate, but existing populations could be

damaged during soil or water movement. Changes to existing climatic and precipitation patterns, perhaps as a result of global environmental change, could also impact this species. For example, average temperatures are projected to increase and precipitation is generally expected to increase over western North America (U.S. Environmental Protection Agency [EPA] 1997, Watson et al. 2001). A document about climate change and Colorado by the EPA reports that average temperatures have increased by 4.1 ºF and precipitation has decreased by up to 20 percent in some areas of Colorado over the last century (EPA 1997). Over the next century, climate models predict that temperatures in Colorado could increase by 3 to 4 ºF (with a range of 1 to 8 ºF) in the spring and fall and by 5 to 6 ºF (with a range of 2 to 12 ºF) in the summer and winter. Precipitation is estimated to increase by 10 percent in spring and fall, increase by 20 to 70 percent in the winter, and create more thunderstorms in the summer (without a significant change in precipitation total) (EPA 1997). Climate change and other potential changes to a suite of environmental variables could affect plant community composition by altering establishment, growth, reproduction, and death of plants. Environmental stochasticity can also affect pollinator activity and behavior. The effects of herbivores on *T. rothrockii* are unknown. Although *T. rothrockii* may not be targeted because it is so small and occurs in areas that are sparsely vegetated and steep, grazing activity can incidentally trample plants or cascade soil down slopes. The effect of native mammal or insect herbivores is not known. *Townsendia rothrockii* is known from approximately 35 scattered occurrences in a limited range with high topographical heterogeneity; the amount of gene flow, genetic variability, and inbreeding is unknown for this species.

## *Conservation Status of the Species in USFS Region 2*

*Townsendia rothrockii* is a species of special concern because it is geographically limited with potential threats to existing populations and habitat. The viability of this species within USFS Region 2 is difficult to ascertain because its full distribution and abundance are unknown and demographic parameters have not been studied. *Townsendia rothrockii* is mainly found on USFS Region 2 lands, but it is not specifically protected as a sensitive species. Road activities, motorized and non-motorized recreation, exotic species invasion, and environmental fluctuations potentially threaten this species. Much information is lacking on the abundance, distribution, and biology of *T. rothrockii*. This species appears to be adaptable to a wide range of environmental conditions throughout central and southwestern Colorado, which may increase its long-term resiliency. However, it is difficult to predict the ability of this species to tolerate environmental stochasticity and any future environmental or management changes.

### Population declines

Based on the existing estimates of abundance, we are unable to conclude that the distribution or abundance of *Townsendia rothrockii* is declining, expanding, or remaining stable throughout its range. Abundance estimates ranged from “scarce” and “infrequent” to “200+”, but there were only estimates for five of the 35 occurrences of this species (Colorado Natural Heritage Program 2003, University of Colorado Herbarium 2003). There have been no detailed status reports or intensive surveys for *T. rothrockii*. Because of its wide elevational range and its presumed ecological tolerance, there may be more occurrences of this species yet to be discovered, especially in infrequently surveyed areas away from trails, roads, and passes. The rate at which this species disperses and colonizes new locations is unknown because we know little about its dispersal and establishment capabilities.

### Habitat variation and risk

Although *Townsendia rothrockii* appears to be locally restricted to certain exposed substrates, this species appears to inhabit a range of microhabitats, such as lava cliffs, talus slopes, and alpine fellfields. Inhabiting different habitats over a range of elevations and within different landscape contexts may somewhat insulate *T. rothrockii* from extinction by one particular factor. The microhabitat requirements for *T. rothrockii* are largely undefined. Potential risks within the habitats could include competition from surrounding vegetation, lack of suitable germination sites, inadequate pollinator habitat, barriers to gene flow, conditions too harsh for adequate growth and development (e.g., sedimentation, trampling), or other fluctuations in disturbance processes that could affect existing populations or creation of habitat.

The optimal type, size, frequency, and intensity of disturbances required to sustain populations of *Townsendia rothrockii* are not known. This species exists in disturbed and sparsely vegetated areas, but it is difficult to determine how much disturbance is enough and how much disturbance is too much. Natural disturbances (e.g., erosion) and current and historical land uses (e.g., prescribed burning, grazing, thinning, mining) may play or may have played a beneficial role

in creating suitable habitat for *T. rothrockii*, but they also could be or could have been detrimental to existing individuals, depending on location and intensity. Also, disturbance regimes most likely vary among the different habitat types. For example, *T. rothrockii* populations in steep, alpine tundra habitat may be less susceptible to fire or non-native plant invasions than lower elevation populations in ponderosa pine habitat. Some occurrences of this species are found in popular recreational areas and are thus susceptible to direct damage from off-highway vehicles, hikers, and sightseers. The inaccessibility of some *T. rothrockii* occurrences in steep, loose, alpine terrain may help to protect those populations from human and herbivore impacts. It is difficult to predict the spread of non-native invasive plants and potential risk of alteration to plant communities. Specific populations could be at a greater risk than other populations, depending on the landscape context, such as proximity to roads and microhabitat characteristics.

As a result of human influences on the environment and the unpredictable effects of environmental fluctuations, significant habitat variation and risk may exist for *Townsendia rothrockii* within USFS Region 2.

## *Potential Management of the Species in USFS Region 2*

Quantitative demographic monitoring and detailed biological and ecological studies of *Townsendia rothrockii* populations and its habitat on USFS Region 2 lands have not occurred. Based on the available information, we can only hypothesize how changes in the environment may affect the abundance, distribution, and long-term persistence of this species.

### Management implications

*Townsendia rothrockii* populations and habitat may be at risk as a result of management activities within the range. Possible human-related threats to existing populations of this species include off-road (or off-trail) motorized and non-motorized activities, road maintenance and sedimentation, mining activities, and introduction of non-native species. Currently, there is some protection of this species through travel management plans and regulations requiring surveys before construction on USFS and BLM lands. The exposure and response of *T. rothrockii* to grazing, prescribed fires, thinning, or timber harvest is unknown. It is possible that these activities could beneficially reduce litter and interspecific competition and encourage germination and growth. The long-term persistence of this species will rely on monitoring the effects of current USFS Region 2 land-use practices and reducing human-related threats to existing populations. For example, creating clearly demarcated and well-constructed trails in popular recreational areas may reduce the effects of direct trampling and erosion/deposition on *T. rothrockii*.

### Potential conservation elements

*Townsendia rothrockii* is a regional endemic with a small number of recorded populations and potentially high vulnerability to human-related activities and environmental changes. The full ecological amplitude of this species and intensity, frequency, size, and type of disturbance optimal for persistence of this species are unknown. The lack of information regarding the colonizing ability, adaptability to changing environmental conditions, sexual and asexual reproductive potential, and genetic variability (e.g., number of apomictic populations) of this species makes it difficult to predict its long-term vulnerability. Surveying high probability habitat for new populations, protecting existing populations from direct damage, documenting and monitoring the effects of current management activities, preventing non-native plant invasions, and studying reproductive and genetic characteristics are key conservation elements for this species on USFS Region 2 lands.

### Tools and practices

There are no existing population monitoring protocols for *Townsendia rothrockii*, and very little is known about the biology, ecology, taxonomy, and spatial distribution of this species. Thus, additional habitat surveys, quantitative species monitoring, taxonomic analyses, and ecological studies are priorities for constructing a current status assessment and conservation plan.

#### *Species inventory and habitat surveys*

Current reports of existing *Townsendia rothrockii* populations provide a useful base of information, but the distribution and total abundance of this species is not sufficiently known to formulate conservation strategies on USFS Region 2 lands. Inventories and a status report on the distribution and abundance of *T. rothrockii* over its range are necessary. Researchers could visit all documented sites to ascertain both current distribution and population status. These sites could be regularly re-visited for update reports. Ascertaining the current abundance of this species would help to

estimate its vulnerability to environmental fluctuations and to monitor the effects of human activities.

Additional surveys of habitat are needed to document the full spatial extent of *Townsendia rothrockii* and to identify the ecological amplitude of this species. The distribution of *T. rothrockii* is widely scattered, with populations or groups of populations spread over a range of elevations in a variety of habitat types. The current distribution map for *T. rothrockii* (**Figure 1**) shows that there are "holes" (areas surrounded by or adjacent to areas with the presence of this species) within the range of this species that could have undocumented populations. For example, *T. rothrockii* is known from one population on the edge of the Rio Grande National Forest, and additional occurrences may exist within that forest. Once survey areas have been identified, researchers could further identify areas of potential habitat using topographic maps, geologic maps, land status maps, and aerial or satellite images. For example, *T. rothrockii* is known from areas with exposed volcanic, limestone, sandstone, granitic, and shale substrates, depending on geographic location. Within areas of suitable parent material, this species is known from topographic landforms such as ridges, scree slopes, and forest openings, and it appears to prefer sparsely vegetated areas. In addition, surveys could use existing populations as a starting point because similar habitats may extend along topographic lines or topographical formations. Locations downslope or downwind from existing populations could be surveyed because *T. rothrockii* seeds are possibly wind, water, and gravity dispersed.

The size and extent of existing populations could be mapped and recorded using global positioning system and geographic information system (GIS) technology. The abundance and size of populations in inaccessible areas may only be estimated. Mapping the extent of each known population of *Townsendia rothrockii* will maintain consistency for future observations and help to estimate density and abundance over time. Mapping populations of *T. rothrockii* will also elucidate the spatial distribution of populations at the regional-level and provide a framework for creating a metapopulation study. Populations in areas slated for various management, maintenance, or disturbance activities could be readily identified.

### *Population monitoring and demographic studies*

Additional information is also needed to gain an understanding of the life cycle, demography, and population trends of *Townsendia rothrockii*. Information is lacking on longevity, germination requirements, seed survival, extent of asexual reproduction, factors affecting flower development, pollination ecology, role of the seed bank, and gene flow between populations. This type of species-specific information would be useful in assessing threats to this species and in estimating species viability. For example, seed bank studies could assess the abundance of seeds to reveal dispersal patterns in this species. Studies of germination needs in the field might elucidate potential limiting factors for the establishment of new individuals. Recording the extent and location of populations with differing ploidy levels will help to assess the genetic variability of this species and to verify its taxonomic status.

No data on population trends for this species are available, and no long-term demographic monitoring has been initiated. Long-term monitoring studies could yield helpful information, such as temporal and spatial patterns of abundance and dormancy; environmental factors that influence abundance (e.g., drought); whether populations are increasing, decreasing, or remaining stable; and the minimum number of plants necessary to perpetuate the species. In addition, identifying apomictic populations and elucidating the genetic differences between and within populations will help to understand metapopulation dynamics and possible taxonomic distinctions between populations.

Understanding certain aspects of demography is a priority in order to provide basic population information, as indicated by these questions:

- What are the rates of survival, longevity, and recruitment?
- What are the population fluctuations from year to year?
- What are the effects of disturbances on demographics?
- What are the role, status, and longevity of the seed bank?
- What is the age structure of the population?
- What is the age at which individuals become reproductive?
- What is the extent of sexual, apomictic, and vegetative reproduction?

- What are the pollinators?
- Are flowers pollen-limited?
- What is the gene flow between populations?

Long-term monitoring programs are required to answer these kinds of questions, but it may take decades for a clear pattern to emerge. Several groups have developed protocols for monitoring population and demographic trends of rare plant species. These protocols can be easily accessed and used to develop specific monitoring plans for use in USFS Region 2. For example, Elzinga et al. (1998) and Hutchings (1994) are general references that provide concrete guidance on designing and implementing quantitative monitoring plans for rare plant species. Austin et al. (1999) and Bonham et al. (2001) provide helpful protocols specifically designed for federal agencies monitoring plants on public lands. In addition, population matrix models that measure individual fitness and population growth provide flexible and powerful metrics for evaluating habitat quality and for identifying the most critical feature of the species' life history (Hayward and McDonald 1997). Deterministic demographic models of single populations are the simplest analyses and are used as powerful tools in making decisions for managing threatened and endangered species (Beissinger and Westphal 1998).

### *Habitat monitoring and management*

General habitat characteristics of *Townsendia rothrockii* have been briefly described. However, there are too many unknowns regarding microhabitat requirements and basic population dynamics to know which factors are critical in maintaining or restoring habitat for this species. Herbarium and occurrence records for this species generally do not identify associated plant species, substrate types, microhabitat characteristics, or landscape context for each population. It is currently not known what types, sizes, intensities, or frequencies of disturbance create and maintain habitat and are tolerated by existing populations of this species. The extent of land management activities and cumulative beneficial or detrimental effects of these management activities on *T. rothrockii* and its habitats have not been studied or monitored. Documenting land management and monitoring habitat could occur in conjunction with population monitoring efforts in order to associate population trends with environmental conditions.

Some examples of management practices that would protect *Townsendia rothrockii* habitat include restricting off-highway vehicle traffic, encouraging hikers to use trails, prohibiting the collection of native plants, and preventing the spread and establishment of non-native invasive species. Habitat management could also consider issues related to the surrounding landscape, such as pollinator habitat needs, herbivore movement patterns, and trail proximity and position in relation to population locations.

### *Biological and ecological studies*

Information regarding habitat requirements, establishment, reproduction, dispersal, relationship with herbivores, competition with other species, and overall persistence has not been studied for *Townsendia rothrockii*. Beaman (1957) provided information on how apomictic *Townsendia* plants can be identified by a high number of aborted pollen grains, evidenced by grains without nuclei. Samples could be taken from each of the *T. rothrockii* populations to identify the prevalence and geographic range of apomictic populations. The response of *T. rothrockii* to habitat changes is not known in sufficient detail to evaluate the effects of changes in disturbance patterns. Research studies to evaluate the effects of erosion and sedimentation, non-native plant species, succession, global climate changes, and other environmental fluctuations would provide valuable input to the development of conservation strategies and management programs. The types of monitoring studies required to understand how this species responds to environmental fluctuations, changes in the disturbance regime, or natural succession would be complex and could take decades. For example, precipitation fluctuations have the potential to affect erosion rates, germination success, pollinator population trends, timing of flowering, and/or growth of surrounding vegetation. It will be difficult to determine to what extent disturbances are necessary to create habitat and/or to maintain a population, what disturbance intensity and frequency may be most appropriate, and what factors would result in local extirpation of a population.

### *Availability of reliable restoration methods*

The successful production and germination of *Townsendia rothrockii* seedlings in garden/greenhouse environments introduces the possibility of restoration efforts, if necessary. Germination and transplantation studies in natural environments would be helpful if populations are at risk of extirpation.

## *Information Needs and Research Priorities*

Based on our current understanding of *Townsendia rothrockii*, we can identify research priorities where additional information will help to develop management objectives, to initiate monitoring and research programs, and to inform a conservation plan. To address these data gaps, information can be obtained through surveys, long-term monitoring plans, and extended research programs. There is so little known about the biology and ecology of this species that there are a large number of research projects that could be implemented.

Re-visiting all populations, estimating current abundance, assessing imminent threats, measuring demographic parameters, studying genetic variability (e.g., apomictic populations), and determining ecological needs and limitations are of primary importance to further the understanding of *Townsendia rothrockii* in USFS Region 2. The following types of studies would supplement basic knowledge regarding this species:

- Re-visiting and detailed mapping of existing populations
- Surveying for new populations
- Addressing imminent threats to known populations
- Documenting and monitoring current land management practices
- Defining and measuring microhabitat characteristics
- Measuring demographic parameters using long-term monitoring plots
- Analyzing genetics to assess gene flow and variability (e.g., apomixis) throughout range
- Conducting studies related to reproductive biology, including breeding system, germination trials, dispersal capabilities, pollinator surveys, mycorrhizal associations, and seedbank analyses

This list is ordered from inventory activities to determine the current status of *Townsendia rothrockii* (e.g., inventories of existing populations, identifying any immediately threatened populations) to more complex, biological studies (e.g., studies of demography, reproduction, habitat needs).

Additional research and data that may be useful but are not incorporated into this assessment include aspects related to managing data for efficient use. Data acquired during surveys, inventories, monitoring programs, and research projects are most easily accessible if they are entered into an automated relational database. Such a database should be integrated with GIS and allow queries and activities such as the following:

- Efficient incorporation of data in the field
- Generation of location and habitat maps and identification of population locations
- Characterization of associated habitat types
- Identification of population trends over time
- Identification of data gaps that require further information gathering
- Easy modification as additional information becomes available

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# DEFINITIONS

**Acaulescent –** With a stem so short that leaves are clustered in a basal rosette.

**Achene –** Small, dry fruit with a close-fitting wall surrounding a single seed.

**Amplitude –** Breadth or range.

**Annual –** A plant that completes its entire life cycle in one growing season.

**Anther –** Part of the flower reproductive structure (stamen) that bears pollen.

**Apomixis –** Ability of some plant species to reproduce asexually with seeds.

**Asexual reproduction –** Any form of reproduction not involving the union of gametes.

**Bract –** Reduced, modified leaf associated with flowers.

**Calyx –** The collective name for sepals.

**Caudex –** Short, swollen, often woody portion of a plant stem that is at or beneath ground level on top of a taproot. This structure functions in new stem production, serves as a storage organ, and/or produces short rhizomes.

**Caulescent –** Producing a well-developed stem above ground.

**Corolla –** Portion of flower comprised of petals.

**Demographics –** The study of fecundity and mortality parameters that are used to predict population changes.

**Diploid –** Containing a full set of genetic material comprised of a paired set of chromosomes, usually one set from each parent.

**Dormancy –** A period of growth inactivity in seeds, buds, bulbs, and other plant organs even when environmental conditions normally required for growth are met.

**Endangered –** Defined in the Endangered Species Act as a species, subspecies, or variety likely to become extinct in the foreseeable future throughout all of its range or extirpated in a significant portion of its range.

**Endemic –** A population or species with narrow physiological constraints or other restrictions, which limit it to a special habitat or a very restricted geographic range, or both.

**Entire –** Having a margin that lacks any toothing or division, as the leaves of some plants.

**Fellfield –** Alpine community characterized by rocky ground, dry soils, and cushion plants.

**Fertility –** Reproductive capacity of an organism.

**Fitness –** Success in producing viable and fertile offspring.

**Fruit –** The ripened, seed-containing reproductive structure of a plant.

**G1 ranking –** Critically imperiled globally because of extreme rarity (five or fewer occurrences or very few remaining individuals) or because of some factor making it especially vulnerable to extinction (NatureServe).

**G2 ranking –** Imperiled globally because of rarity (6 to 20 occurrences) or because of factors demonstrably making a species vulnerable to extinction (NatureServe).

**G3 ranking –** Vulnerable throughout its range or found locally in a restricted range (21 to 100 occurrences) or because of other factors making it vulnerable to extinction (NatureServe).

**G4 ranking –** Apparently secure, though it may be quite rare in parts of its range, especially at the periphery (NatureServe).

**G5 ranking –** Demonstrably secure, though it may be quite rare in parts of its range, especially at the periphery (NatureServe).

**Glabrous –** Smooth, without hairs, trichomes, or glands.

**Habitat fragmentation –** The breakup of a continuous landscape containing large patches into smaller, usually more numerous, and less connected patches. Can result in genetic isolation.

**Herbaceous –** Characteristic of an herb (plant with no aboveground persistent woody stem).

**Hybridization –** The result of a cross between two interspecific taxa.

**Inflorescence –** The flowering part of a plant, usually referring to a cluster of flowers.

**Interspecific competition –** Competition for resources between individuals of different species.

**Intraspecific competition –** Competition for resources among individuals of one species.

**Involucre –** Series of bracts surrounding or subtending a flower or inflorescence.

**Lanceolate –** Lance-shaped; much longer than broad, widening above the base and then tapering to the tip.

**Metapopulation –** Group of populations that are linked through migration of individuals.

**Mycorrhiza –** Symbiotic association between a fungus and the root of a higher plant.

**Oblanceolate –** Lance-shaped, but broadest above the middle and tapering to the base.

**Obovate –** Egg-shaped, with the narrower end near the point of attachment.

**Obtuse –** Blunt, with sides coming together at an angle greater than 90 degrees.

**Ovary –** The enlarged portion of the female reproductive structure (pistil) that contains the ovules and develops into the fruit.

**Ovate –** Egg-shaped, with the larger end toward the base (i.e. ovate leaves).

**Pappus –** The crown of hairs, bristles, awns, or scales on the ovary (and achene) of Asteraceae.

**Peduncle –** Stalk of an inflorescence.

**Perennial –** A plant that lives for three or more years and can grow, flower, and set seed for many years; underground parts may regrow new stems in the case of herbaceous plants.

**Phenotype –** The external visible appearance of an organism.

**Phenotypic plasticity –** When members of a species vary in height, leaf size or shape, flowering (or spore-producing time), or other attributes, with changes in light intensity, latitude, elevation, or other site characteristics.

**Phyllaries –** Bracts associated with the involucre of Asteraceae.

**Pistil –** The seed-producing organ of a flower, consisting of a stigma, style, and ovary.

**Plurisetose –** Bearing several projections.

**Pollen –** The male spores in an anther.

**Polycarpic –** Flowering and bearing fruit multiple times.

**Polyploidy –** Having more than two complete sets of chromosomes per cell.

**Population Viability Analysis –** An evaluation to determine the minimum number of plants needed to perpetuate a species into the future, the factors that affect that number, and current population trends for the species being evaluated.

**Propagule –** A reproductive body, usually produced through asexual or vegetative reproduction.

**Pubescent –** Bearing hairs.

**Receptacle –** Enlarged portion of the flower axis, which bears some or all of the flower parts.

**Recruitment –** The addition of new individuals to a population by reproduction.

**Rosette –** A cluster of leaves arranged in a circle, often in a basal position.

**Rosulate –** Clustered into a rosette with a very short stem.

**S1 ranking –** Critically imperiled globally because of extreme rarity (five or fewer occurrences or very few remaining individuals) or because of some factor making it especially vulnerable to extinction (NatureServe).

**S2 ranking –** Imperiled globally because of rarity (6 to 20 occurrences) or because of factors demonstrably making a species vulnerable to extinction (NatureServe).

**Scarious –** Thin, dry, non-green, and membranous.

**Scree –** Accumulation of small rock debris (generally smaller than talus), often at base of cliff or steep slope.

**Sensitive species –** A species whose population viability is a concern due to downward trends in population numbers, density, or habitat capability, as identified by a regional forester (USFS).

**Sepals –** A segment of the calyx.

**Sessile –** Lacking a stalk.

**Sexual reproduction –** Reproduction involving the union of gametes.

**Spatulate –** Shaped like a spoon.

**Stamen –** The pollen-producing structures of a flower; the "male" part of a flower.

**Strigose –** With stiff, straight bristles.

**Succession –** The orderly process of one plant community replacing another.

**Talus –** Accumulation of coarse rock debris (generally larger than scree), often at base of cliff or steep slope.

**Taproot –** Main, central root growing straight down, often stouter than other roots.

**Threatened –** Defined in the Endangered Species Act as a species, subspecies, or variety in danger of becoming endangered within the foreseeable future throughout all or a significant portion of its range.

**Vegetative reproduction –** A form of asexual propagation whereby new individuals develop from specialized multi-cellular structures that often detach from the mother plant.

**Viability –** The capability of a species to persist over time. A viable species consists of self-sustaining and interacting populations that have sufficient abundance and diversity to persist and adapt over time.

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